A framework for a dynamic interactive 3D GIS for non-expert users

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Abstract

Many substantial geographic information systems (GIS) have been designed for use by expert users. As a result, non-expert users often find them difficult to use. This paper presents a framework to facilitate the use of such GIS by non-expert users. The framework achieves this by allowing the creation of vague visual queries which use data abstraction and relevance feedback to obtain a final result. The data abstraction model is dynamically updated to improve future query performance.

CR Categories: D.1.7 Visual Programming; H.3.3 Information Search and Retrieval, Clustering, Query formulation, Relevance feedback.

Keywords: visual query language, relevance feedback, data abstraction model, geographic information system

1 Introduction

Geographic information systems (GIS) have been predominately designed for expert users with specialized applications (e.g. urban planning). The text query languages that are used in GIS require an in-depth knowledge of the database attributes and relationships. Expert users have such knowledge, however, recently GIS applications have experienced diversification of typical usage to include non-expert users. For example, city and shire councils have developed property GIS services for do-it-yourself searches over the internet. To support these non-expert users, who find traditional GIS text based query languages difficult to use, an easy-to-use query language is required.

This paper presents a framework to facilitate the use of GIS by non-expert users. The framework achieves this by allowing the creation of vague visual queries which use a recently developed technique called relevance feedback to obtain a final result and update a data abstraction model.

The remainder of this paper is structured as follows. Sections 2, 3 and 4 review the current work in the area. Section 5 proposes the new framework and section 6 presents conclusions and future work.

2 Visual Query Languages

Visual query languages reduce the complexity of query formulation to a level suitable for non-expert users of GIS. The main advantage of visual languages is that users can access the database without previously learning a specific query language. Several approaches use the query-by-example metaphor. In this type of approach, the system asks the user to supply a sample of the spatial scene that they are looking for and then searches the database for a match [1].

3 Data Abstraction Models

The visual languages detailed above all have a common limitation. They are all focused on finding spatial matches within the database. To allow even more vague queries that include understanding the intent of the user, one could use a high level user abstraction that classifies the data to be queried. In these query languages, a hierarchical data abstraction model is constructed to group database themes that are loosely related together. This allows a vague query using a certain keyword to discover lateral results through searching the hierarchical data abstraction model [2, 3]. A limitation of these approaches is the maintenance of the hierarchical data abstraction model. This paper proposes to overcome these limitations by using relevance feedback to update the data abstraction model.

4 Relevance Feedback

Good interactive systems will learn from user interaction so that future output will more correctly satisfy users' requests. This has been the driver for the current research into relevance feedback [4, 5], which lately has mainly been in the area of image database retrieval. This paper shows the idea is transferable to spatial relationships in a GIS application intended for non-expert users.

5 Framework for Non-expert Queries in GIS

The framework consists of three major components: A visual language, a data abstraction model and a relevance feedback component. The visual language allows spatial and vague tasks to be performed. A data abstraction model enables vague intent to be discovered through conceptual linkages. Finally, relevance feedback is used to refine the queries and update the data abstraction model to build conceptual linkages dynamically.

5.1 3D Visual Query Language Component

The visual language selected is the query-by-example metaphor type of approach. It uses icon algebraic with spatial operators to build example scenes within a three dimensional editor.

The query scene editor has an X,Y,Z and 3D view to enable icons to be spatially related to each other in the three orthogonal plans. Spatial data is grouped into features like mountains and rivers. There is an icon representation for each of these features. Some features are represented as a line icon (e.g. rivers and roads). The start and end points of the line can be moved in the 3 orthogonal planes. The icons that represent the remaining features (e.g. mountains and forests) use a 3D bounded box. The icons themselves can be stretched to allow relative size to be spatial represented.

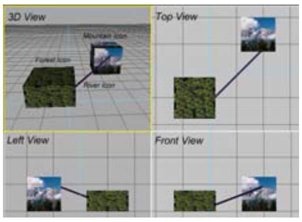

Figure 1 – Icon Graphics

A graphical representation is added to the icon's bounded box surfaces to give a more realistic scene. The scene in figure 1 represents a spatial query where a river runs from a mountain into a forest. The conceptual intention of the query will be processed by the data abstraction model. From the icon scene the spatial relationships are extracted that define the query. The spatial relationships that can be obtained from the scene builder are disjoint, touches, within and intersect. The spatial relationships of union, and relates are discovered implicitly through the relevance feedback process. The spatial operator AND is the default for the icons added to a scene. The OR and NOT operators can be used in the scene by dragging and dropping them onto the related icon.

5.2 Data Abstraction Model Component

A network data abstraction model will be used to aid non-expert queries. This type of model is a variation on the hierarchical approach. The flexible network structure overcomes the limitations imposed by a hierarchical approach to augment new conceptual relationships. The hierarchical approach uses a tree structure to build linkages from a parent node to children nodes. The network approach builds the linkages as a peer-to-peer relationship. The structure of the model is shown in figure 2.

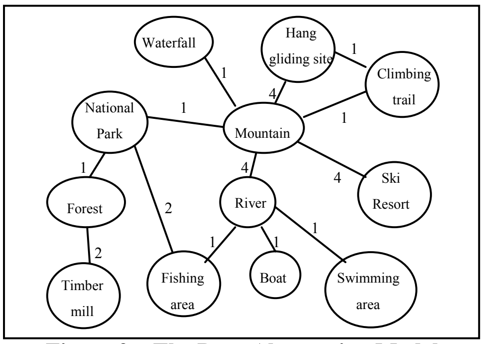

Figure 2 – The Data Abstraction Model

The links between features are designated via a weighted conceptual value. This value defines "how closely related the features are". For example, in figure 2, Mountain is more closely related to Waterfall than to River. In addition, if a path through the network can be found that connects features, then the conceptual value is the sum of the values on each link. For instance, Mountain relates to Forest via path Mountain-National Park-Forest with a conceptual relevance of 2 (i.e. 1+1=2).

New links between features can be connected at any time. In theory the network could be fully meshed (i.e. a direct link between every feature). The link values can be incremented or decremented to change relationships between features. The direct links between features have a range from 1 to 10 on their weighted conceptual value. A value of 1 suggests a strong conceptual relationship. If the link value increments above 10, then the link is removed from the network. If new links between features are discovered a direct linkage is added to the network with a value of 10. The conceptual linkages are initially setup by the system and relevance feedback is used to dynamically maintain the conceptual linkages.

The features included in the visual query are used as the starting nodes in the data abstraction model. Initially, the nodes that are a conceptual cost of one from each of the starting nodes are included into the query. So for the query of figure 1 and using the data abstraction model of figure 2 the features that have a strong conceptual relationship (i.e. link value = 1) are National Park, Waterfall, Climbing Trail, Fishing Area, Boat and Swimming Area. These features are combined with the spatial relationship to refine the overall query.

For queries that return zero results the query can easily be generalized by increasing the conceptual link value used in the abstraction query. For example, now include features that are a link value of 2 (either direct or indirect). The generalized query would now include Timber Mill and Hang Gliding Site features.

5.3 Relevance Feedback Component

The relevance feedback approach used will learn a) which spatial characteristics of the data are important and b) the conceptual meaning of the query. The spatial characteristic learnt will use a weighting algorithm as used in [4] to readjust the query. The conceptual meaning learnt will increment and decrement the conceptual links in the data abstraction model.

For example, consider figure 2 for queries about River features, the abstract query would return the strong conceptual linkages Fishing Area, Boat and Swimming Area (i.e. link = 1). If the user marked a correct match for Boat and incorrect for Swimming Area, then the link to Boat would be decrement (in this case it is already at lowest value so it stays at 1) and the link to Swimming Area would be incremented.

The results of the query will be presented to the user as a series of scene in separate GIS windows. These scenes will contain the specified features as well as any conceptual features that have been discovered through the abstraction model. The user selects matches that they feel are correct. This is the process used to refine the query and update the data abstraction model.

6 Conclusions and Future Work

The visual query language proposed can define spatial relationships for a 3D interface. A relevance feedback approach is unique because it is used to update the data abstraction model. The data abstraction model is dynamic and flexible. It can adjust to conceptual relationships that change over time or from users to users. It can generalize by traversing more of the abstraction network to discover even vaguer relationships.

A suitable problem solving exercise is being developed in order to evaluate the proposed framework. More information exists at http://www.bee.qut.edu.au/people/walkerar/.

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